Connecting Jason-3 to the Long-Term Sea Level Record: Results from Harvest and New Regional Campaigns

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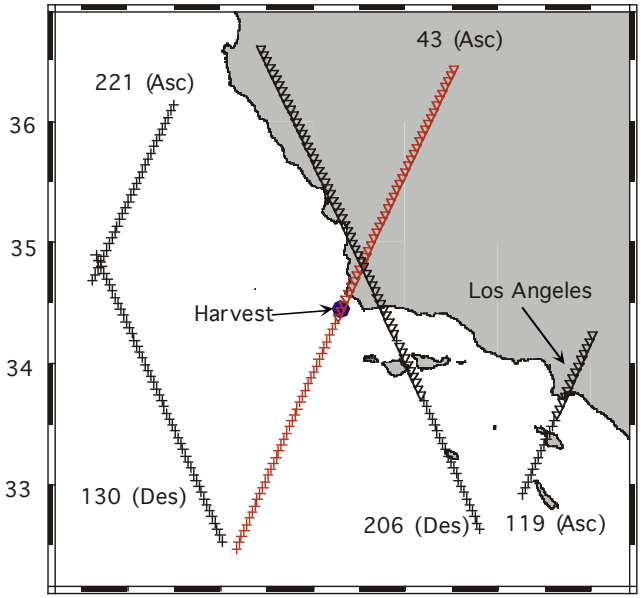
October 25, 2017
Ocean Surface Topography Science Team Meeting
Miami, FL USA

Harvest Platform

- **NASA Prime Verification Site for High-Accuracy (Jason-class) Altimetry**
  - Open-ocean location along 10-d repeat track
  - 10-km off coast of central California
- **Provides independent measure of local geocentric sea level**
  - Precise GPS receivers
  - Redundant tide gauges (Bubbler, radar, lidar)
  - Local survey
- **Yields absolute SSH bias**
  - Also provides for monitoring of ancillary parameters (e.g., wet troposphere delay)
- **Rich in-situ data set representing over 25 years of continuous monitoring**
  - 365 T/P overflights spanning 10 years (1992–2002)
  - 259 Jason-1 overflights spanning 7 years (2002–2009)
  - 303 Jason-2 overflights spanning 8 years (2008–2016)
  - 62 Jason-3 overflights and counting (2016–)
    - In formation 80 seconds after Jason-2 until 10/2/16.
    - 23 dual J2/J3 overflights before J2 orbit shifted.
- **Platform production still on hold**
  - Future of platform not assured

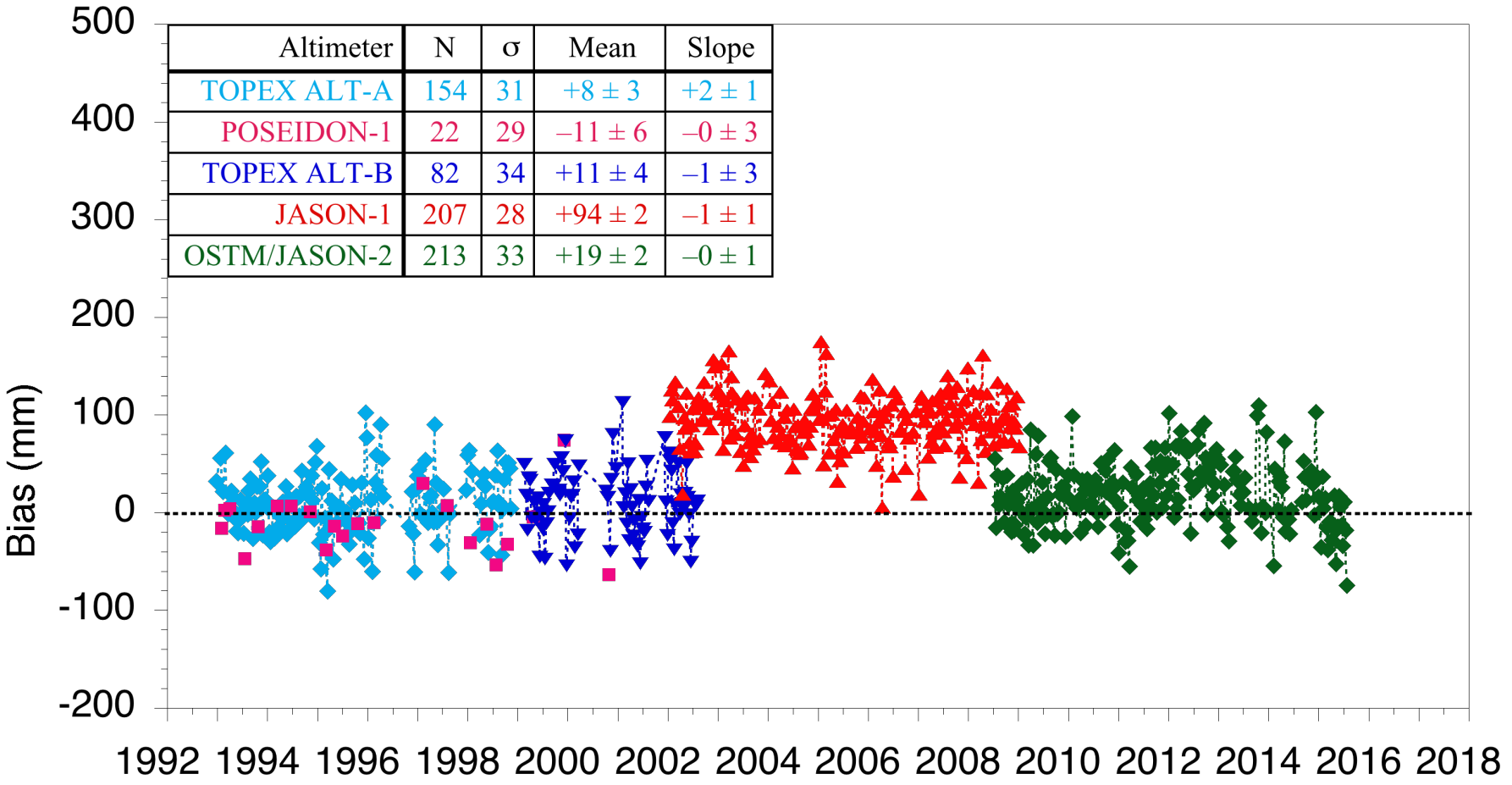


Harvest Long-Term SSH Calibration Record

On Eve of Jason-3 Launch

Nominal Time Series:

T/P: MGDR + reprocessed orbits (*Lemoine et al.*, 2010) and wet trop. (*Brown et al.*, 2009); **Jason-1:** GDR-C; **Jason-2**: GDR-D

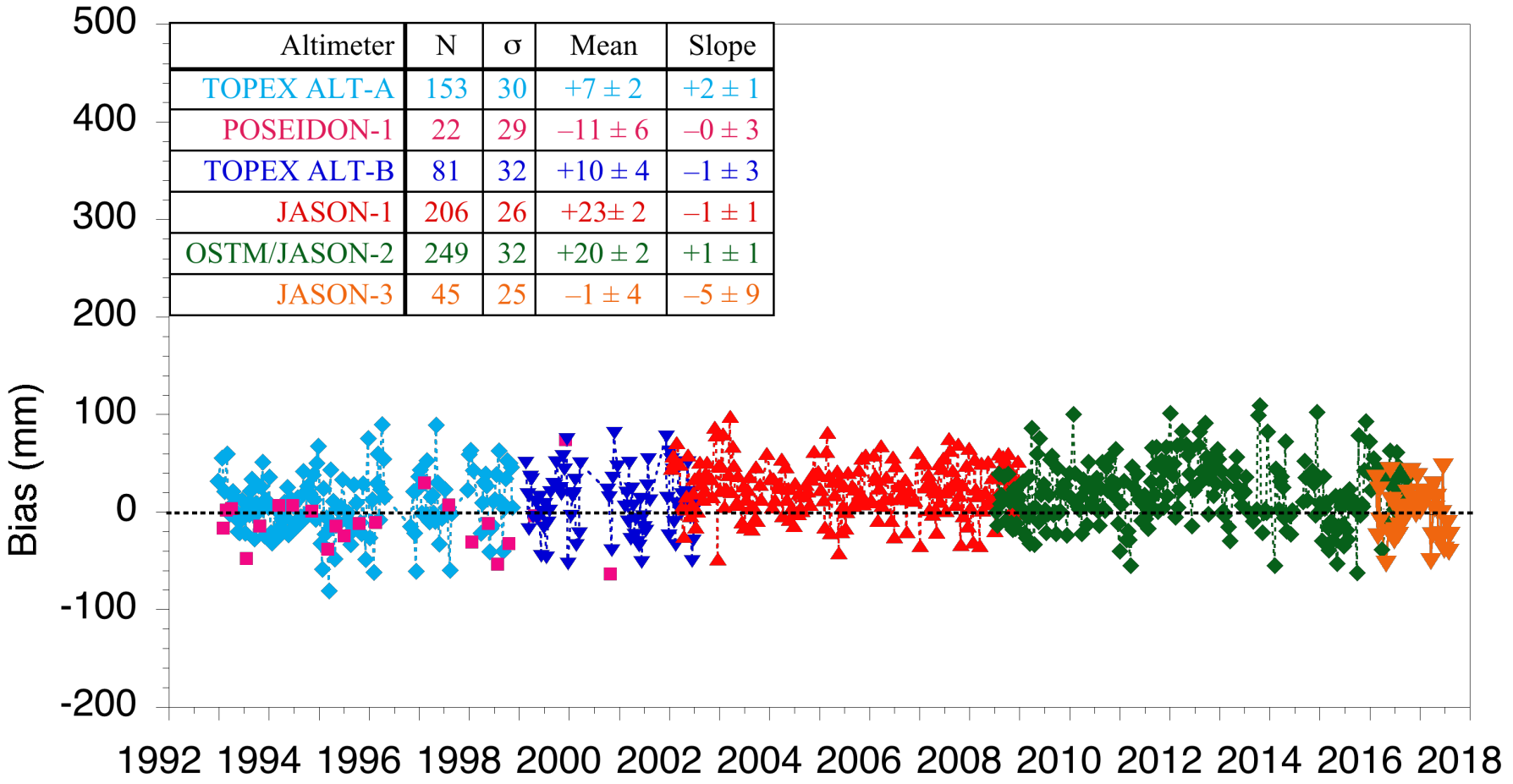


Harvest Long-Term SSH Calibration Record

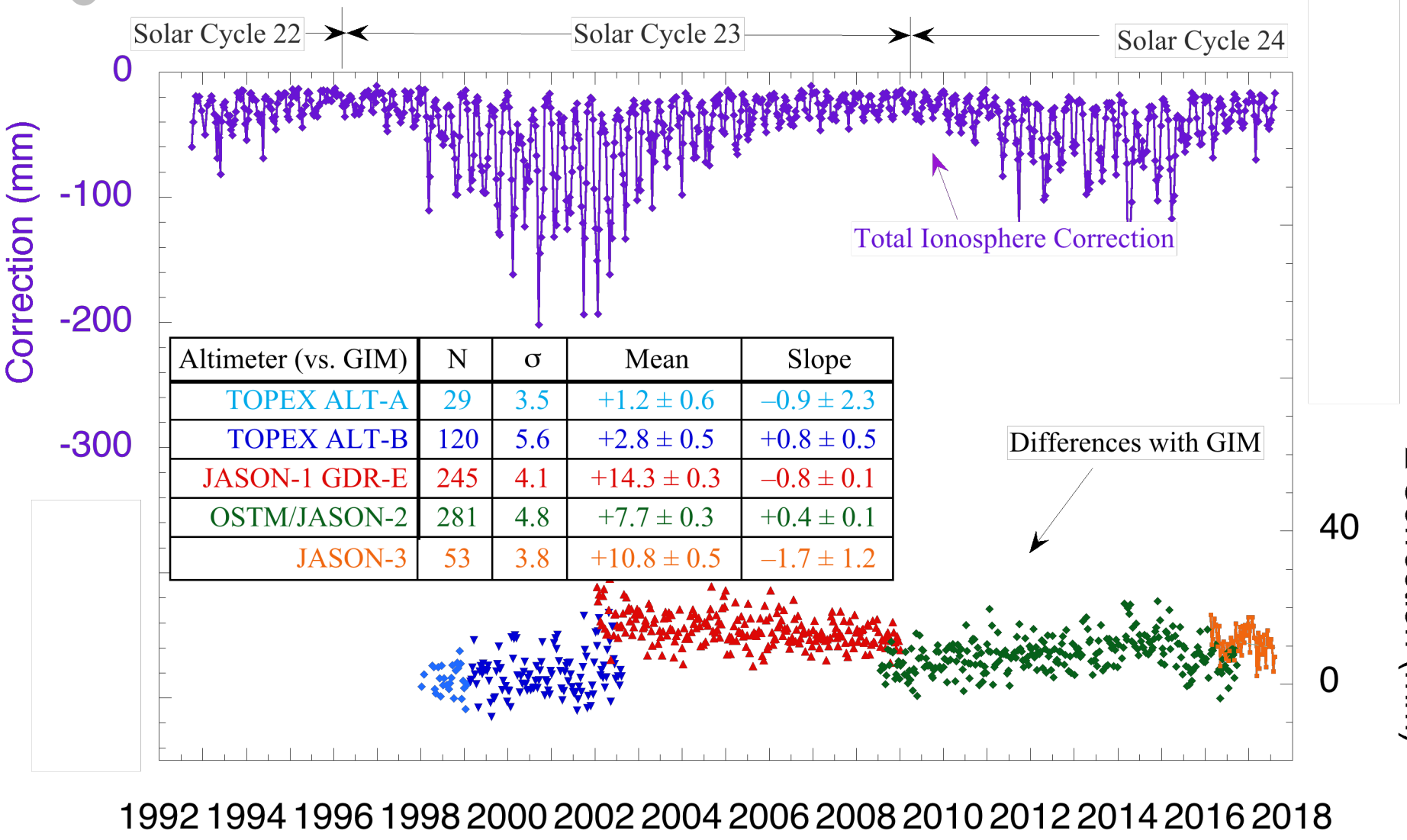
Current Best Estimate

Nominal Time Series:

T/P: MGDR + reprocessed orbits (*Lemoine et al.*, 2010) and wet trop. (*Brown et al.*, 2009); **Jason-1:** GDR-E; **Jason-2**: GDR-D; **Jason-3**: GDR-T

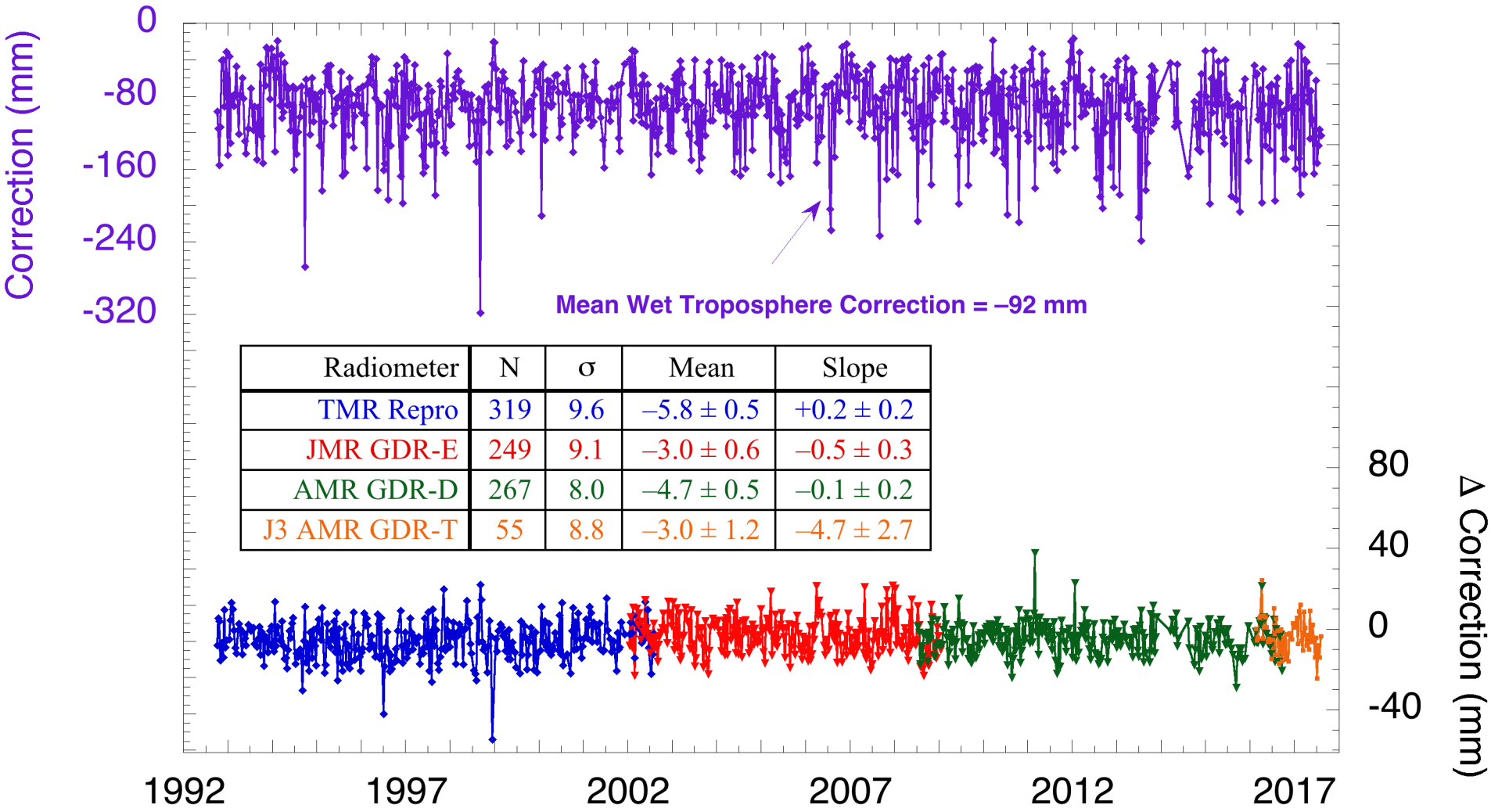


Ionosphere: Ku-Band Altimeter vs. GPS



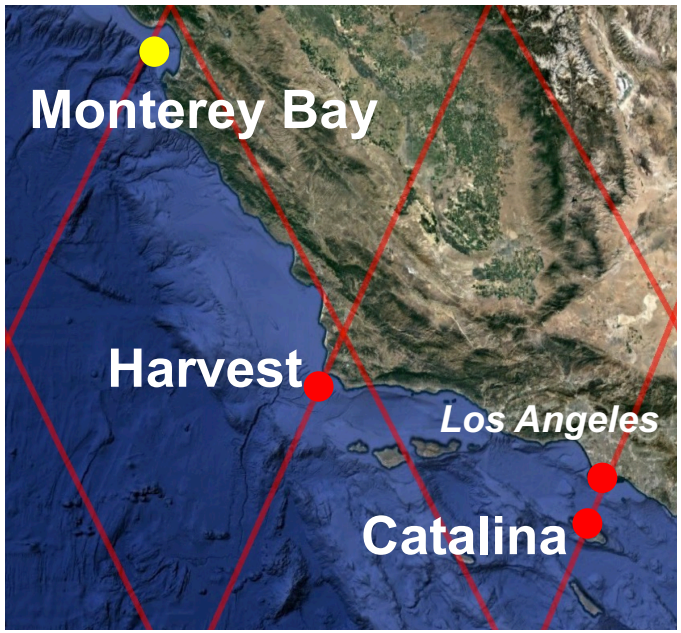
Altimeter (vs. GIM)	N	σ	Mean	Slope
TOPEX ALT-A	29	3.5	+1.2 ± 0.6	–0.9 ± 2.3
TOPEX ALT-B	120	5.6	+2.8 ± 0.5	+0.8 ± 0.5
JASON-1 GDR-E	245	4.1	+14.3 ± 0.3	–0.8 ± 0.1
OSTM/JASON-2	281	4.8	+7.7 ± 0.3	+0.4 ± 0.1
JASON-3	53	3.8	+10.8 ± 0.5	–1.7 ± 1.2

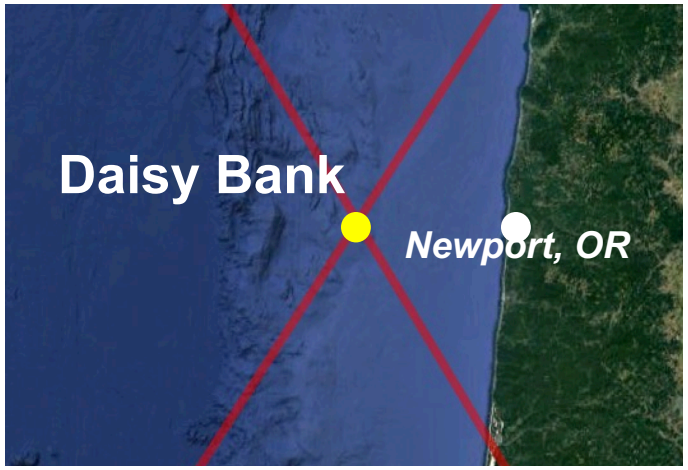
Wet Troposphere: Radiometer vs. GPS

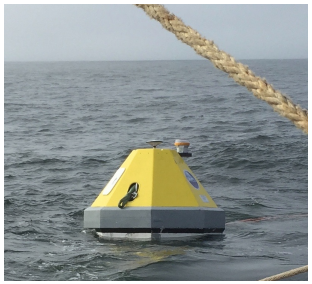


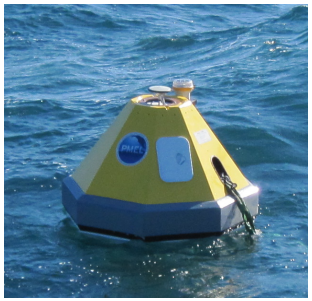
Radiometer	N	σ	Mean	Slope
TMR Repro	319	9.6	–5.8 ± 0.5	+0.2 ± 0.2
JMR GDR-E	249	9.1	–3.0 ± 0.6	–0.5 ± 0.3
AMR GDR-D	267	8.0	–4.7 ± 0.5	–0.1 ± 0.2
J3 AMR GDR-T	55	8.8	–3.0 ± 1.2	–4.7 ± 2.7

Regional Campaigns: Expanding the Calibration Footprint









Monterey Bay

Summer 2017 GPS Buoy Campaign for SWOT (but also near Jason pass).

Harvest

NASA Prime Verification Site for High-Accuracy (Jason-class) Altimetry.

Stable and Accurate Calibration Record Spanning 25 Years.

Catalina Island

Provisional calibration site est. 6/17 (lidar tide gauge + existing GPS).

Daisy Bank

Summer 2016 GPS Buoy Campaign at Jason Crossover Location

GPS Buoy Project

- Joint NASA JPL, NOAA PMEL and U. Washington project funded through NASA ROSES call (Physical Oceanography)*

OBJECTIVES:

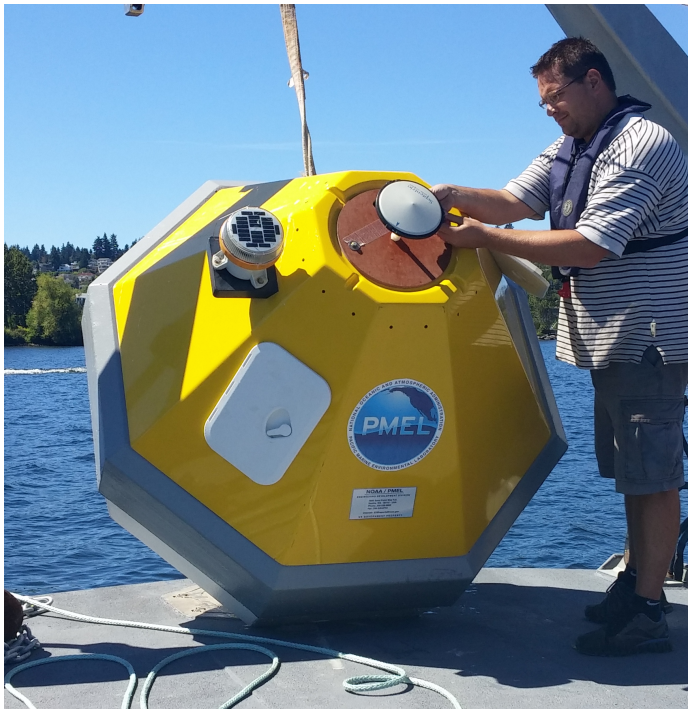
- Design, build and test a modular, low-power, robust, high-accuracy GNSS measurement system for long-term, continuous and autonomous operations on ocean- and cryosphere-observing platforms.
- Probe the limits of new kinematic precise-point positioning (PPP) techniques for accurately determining sea-surface height, and recovering neutral and charged atmosphere characteristics.
- Explore potential scientific benefits—in the fields of physical oceanography, weather and space weather—of accurate GNSS observations from a global ocean network of floating platforms.

**Extending the Reach of the Global GNSS Network to the World's Oceans: A Prototype Buoy for Monitoring Sea Surface Height, Troposphere and Space Weather*, B. Haines, S. Brown, S. Desai, A. Komjathy, R. Kwok, D. Stowers, C. Meinig and J. Morison.

Prototype Precision GPS Buoy

FEATURES

- Integrated low-power (~1 W), dual-frequency GPS system (Septentrio)
- Miniaturized digital compass/accelerometer.
- Iridium communications (presently used for basic heartbeat information).
- Adaptable to multiple floating platforms (e.g., buoys, wave gliders).
- Enables geodetic quality solutions without nearby reference stations.



DEVELOPMENT AND TESTING

- Buoy tested successfully under progressively more challenging conditions:

✓ *Lake Washington (Aug. 7–12, 2015).*

✓ *Puget Sound (Nov. 10 to Dec. 14, 2015).*

✓ *Daisy Bank: open ocean Jason crossover location (May 11 to Sep. 8, 2016).*

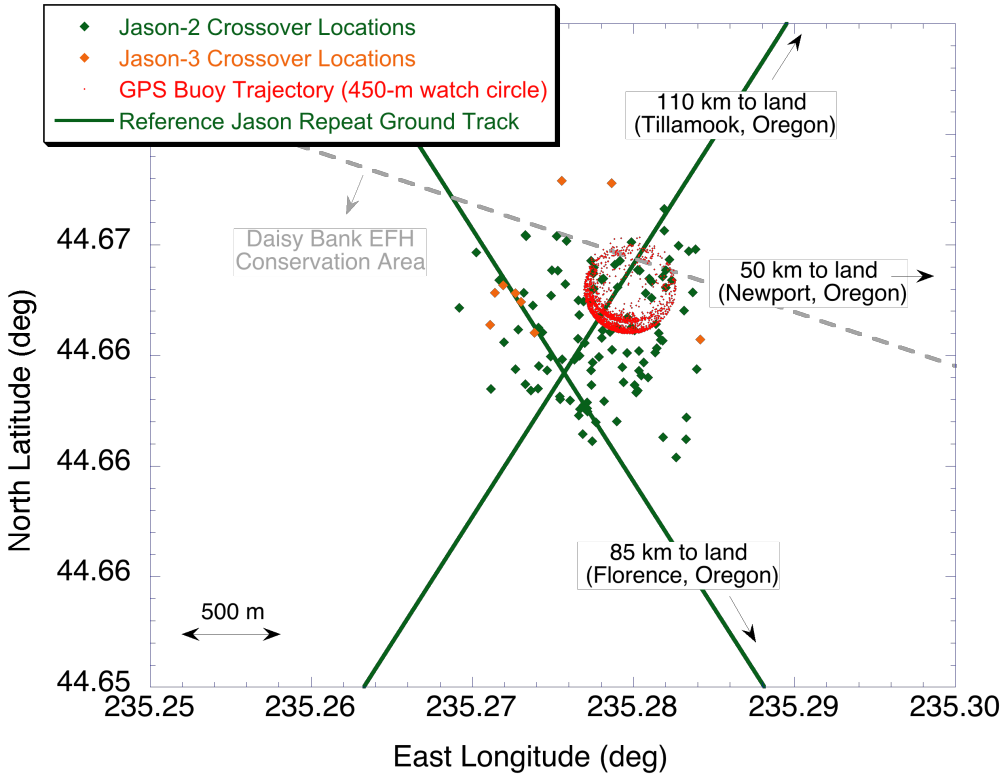
✓ *Monterey Bay: SWOT Pilot Experiment (June 22 to September 7, 2017).*

⇨ **Total of 236 days in the water** (20 days of data from Monterey Bay data lost due to failed USB drive).

GPS Buoy Campaigns

DAISY BANK CLOSEUP

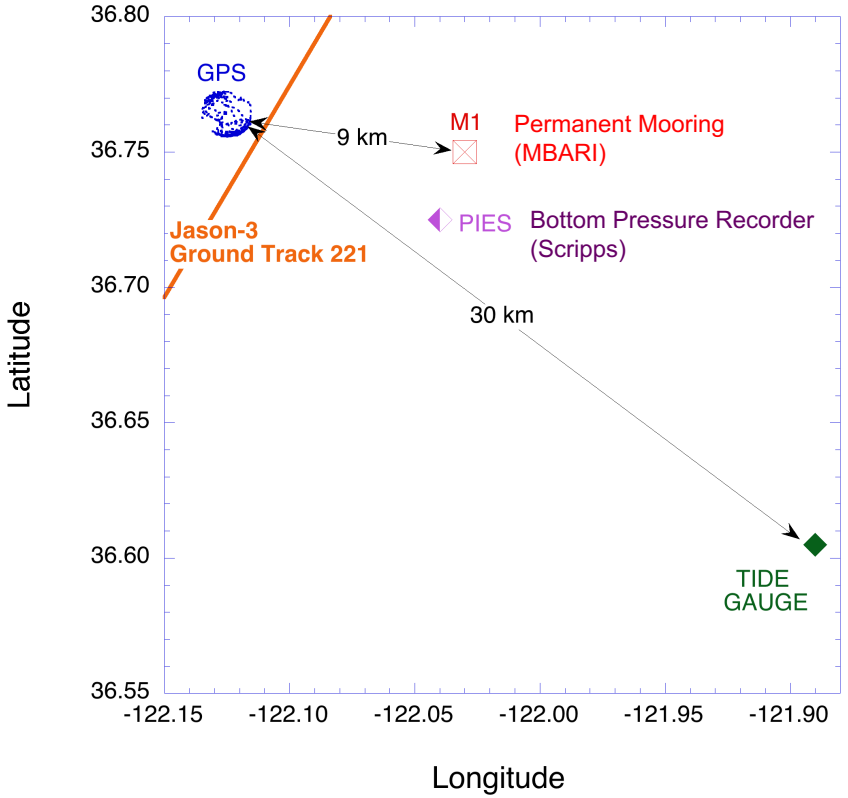
~200-m depth



Deployment spanned 24 dual Jason-2/3 overflights

MONTEREY BAY CLOSEUP

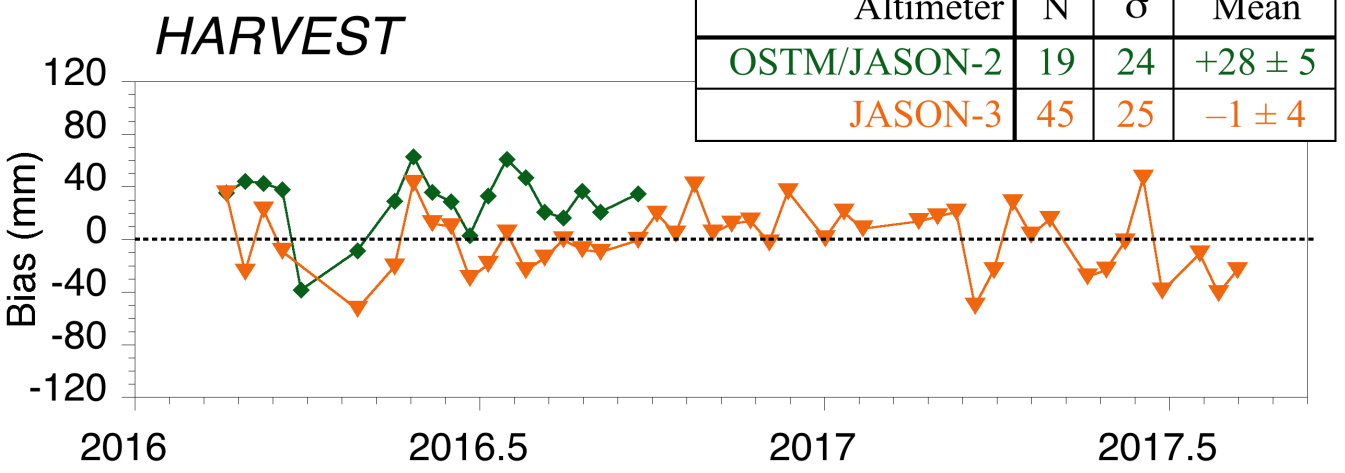
~1000-m depth



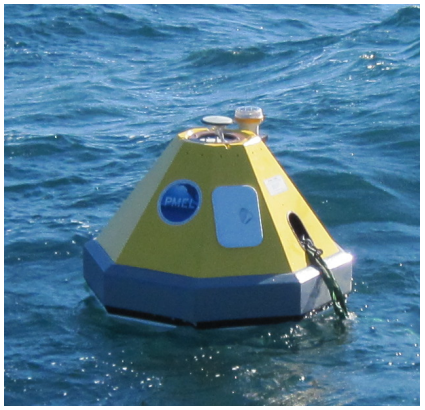
Deployment spanned 6 Jason-3 overflights

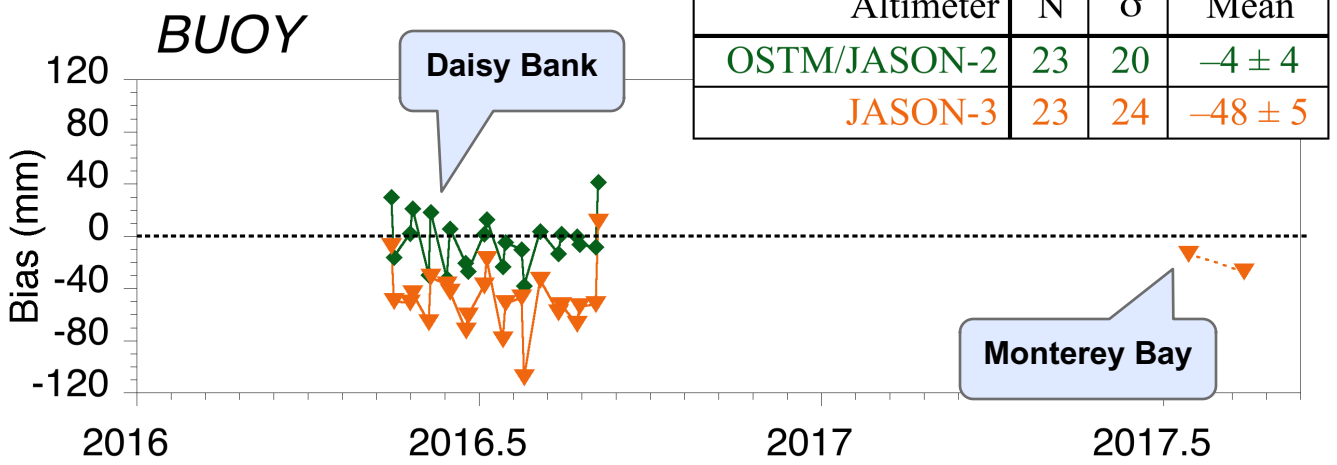
SSH Bias: Harvest vs. Buoy

Comparable Results for the Jason-3 Era



Altimeter	N	σ	Mean
OSTM/JASON-2	19	24	+28 ± 5
JASON-3	45	25	–1 ± 4

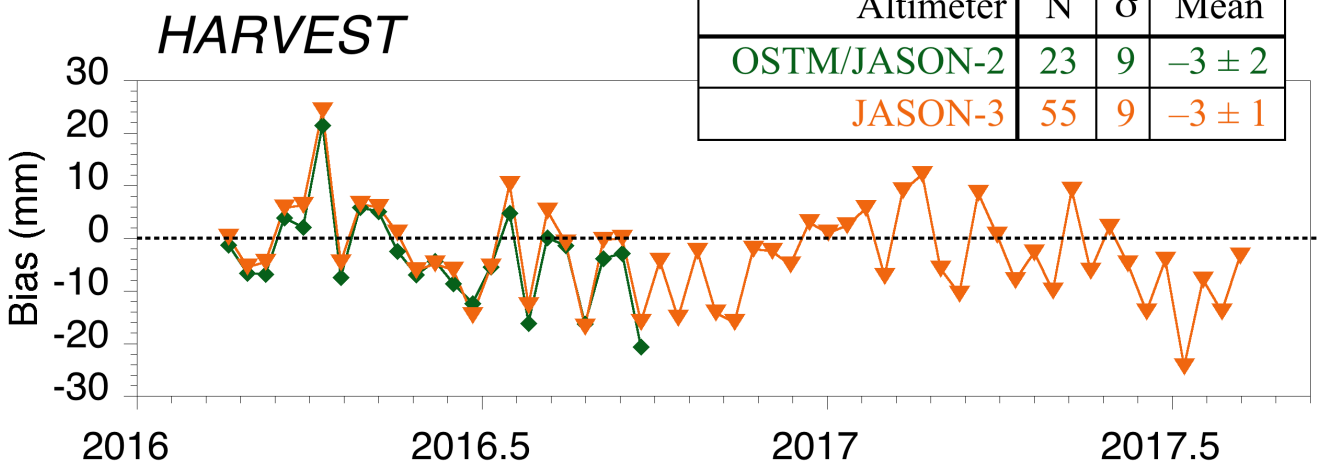




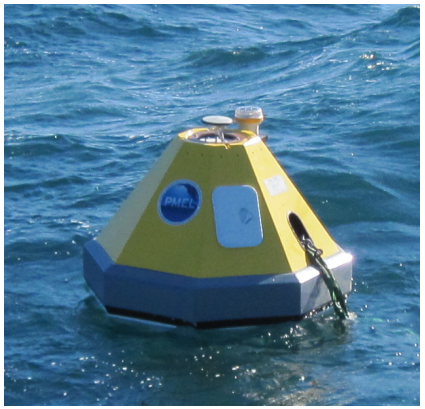
Altimeter	N	σ	Mean
OSTM/JASON-2	23	20	–4 ± 4
JASON-3	23	24	–48 ± 5

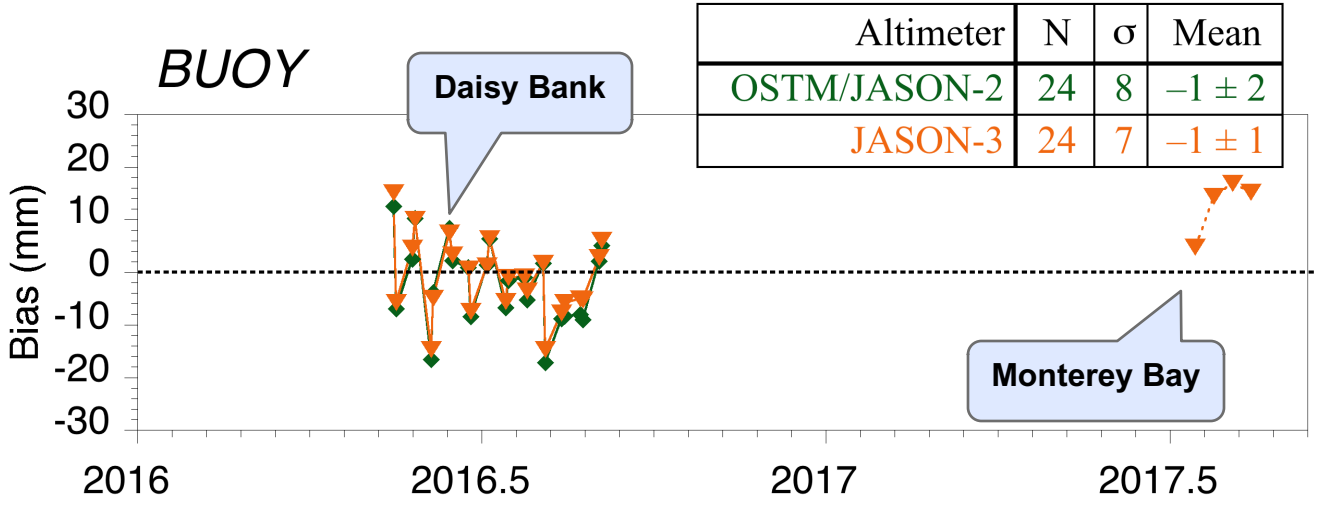
GPS Wet Path Delay Calibration: Harvest vs. Buoy

Comparable Results for the Jason-3 Era



Altimeter	N	σ	Mean
OSTM/JASON-2	23	9	–3 ± 2
JASON-3	55	9	–3 ± 1

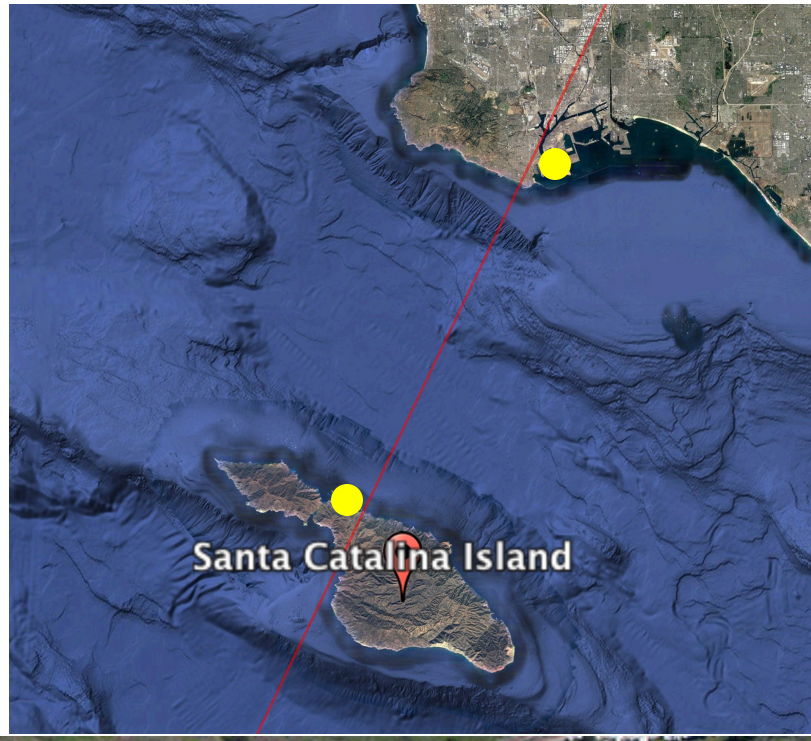




Altimeter	N	σ	Mean
OSTM/JASON-2	24	8	–1 ± 2
JASON-3	24	7	–1 ± 1

Expanding the Calibration Footprint of Harvest:
Provisional Site on Santa Catalina Island
(see Masters et al. poster for additional information)

- **Lidar-based tide gauge installed June 2017**
  - Wrigley Institute for Environmental Studies (U. of Southern California) near Two Harbors.
  - 100 m from permanent GPS site (est. 1995)
  - ~2 km from Jason-3 ground track (Pass 119, adjacent to and west of Harvest Pass 43).
  - ~20 km (along Jason pass 119) to center of San Pedro Channel.
  - ~40 km (along Jason pass 119) to historical Los Angeles tide gauge (est. 1923 in San Pedro).
- **Preliminary Altimeter (GDR) vs. Tide Gauge (lidar) comparisons are promising**
  - ~15 mm repeatability (N = 5 Jason-3 overflights).



Summary

- **Absolute SSH bias from Harvest***
  - Jason-3: –1 ± 15 mm for GDR-T (Cycles 1 to 55 with N = 45)
  - Jason-2: +20 ± 15 mm for GDR-D (Cycles 1 to 303 with N = 249)
  - Jason-1: +23 ± 10 mm for GDR-E (Cycles 1 to 259 with N = 206)
- **Relative Jason-2 vs. Jason-3 SSH bias *from dual Harvest overflights*:**
  - Jason-3 SSH lower (by 39 ± 4 mm) than Jason-2 SSH.
  - Comparisons with "orbit-range" suggest SSH bias comes mainly from range.
  - Smaller Jason-3 ionosphere delay (~5 mm).
- **SSH drift at Harvest indistinguishable from zero for all legacy systems**
  - ≤ 1 mm/yr for all systems except TOPEX (Side A). Jason-3 time series too short.
- **Preliminary results from GPS buoy very promising**
  - Returned continuous, high accuracy data for Daisy Bank and Monterey Bay
  - Supported accurate retrievals of SSH, SWH, wet path delay and ionosphere.
  - Competitive with Harvest for all altimeter calibration metrics.
  - Next planned deployment: Summer 2018 at Harvest (TBC) with two buoys.

** Error includes uncertainty in platform vertical*